BIOLOGICAL INTEGRITY OF BEAR CREEK, PARK COUNTY, MONTANA BASED ON THE COMPOSITION AND STRUCTURE OF THE BENTHIC ALGAE COMMUNITY

Prepared for:

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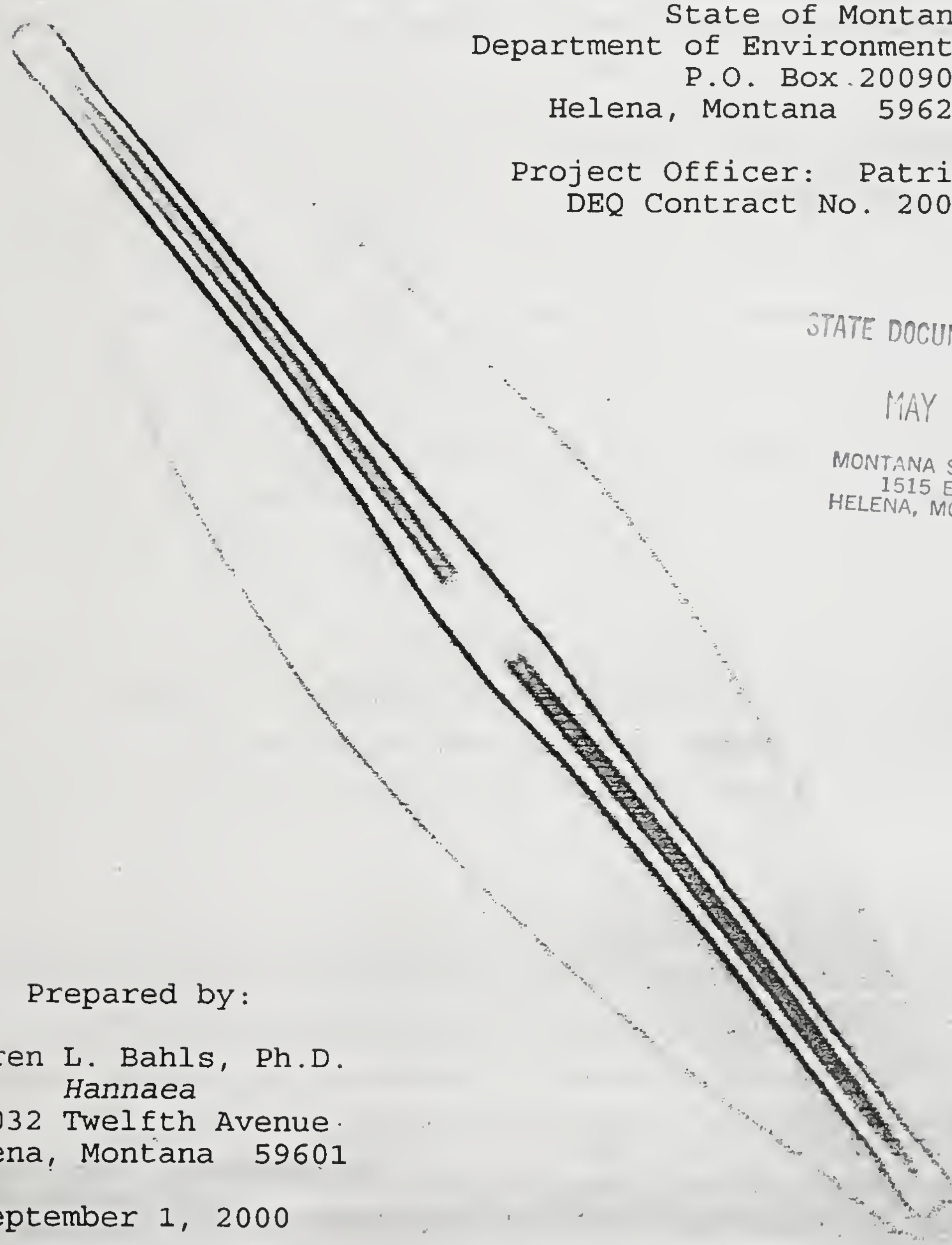

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SUMMARY

On July 13, 2000, a composite periphyton sample was collected from natural substrates at the mouth of Bear Creek in the upper Yellowstone River drainage of southcentral Montana for the purpose of assessing whether Bear Creek is water-quality limited and in need of TMDLs. The sample was collected following DEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

The periphyton of Bear Creek was dominated by diatoms, the chrysophyte *Hydrurus foetidus*, and by the filamentous green alga *Ulothrix*. Cyanobacteria (blue-green algae) were of secondary importance in Bear Creek, indicating that the stream might be receiving some cultural inputs of nutrients. Typically, green and blue-green algae share dominance in streams of the Middle Rockies Ecoregion and dominance by diatoms and green algae may indicate higher than normal levels of nutrient enrichment.

The diatom flora of Bear Creek was dominated by *Hannaea arcus*, the unofficial State Diatom of Montana. This species prefers cold, flowing waters and is reported to be indifferent to small amounts of organic pollution. Major diatom taxa in Bear Creek also included one other "sensitive" species and two species that are somewhat tolerant of pollution.

Diatom association metrics indicated good to excellent water quality, little or no impairment, and full support of aquatic life uses, except for a borderline percent dominant species value (50.85%), which indicated moderate impairment. This dominance by *Hannaea arcus* also resulted in a depressed species diversity index that indicated minor impairment. A small percentage (0.24%) of abnormal diatom cells (again, *Hannaea arcus*) may indicate chronic toxicity from heavy metals in Bear Creek.

INTRODUCTION

This report evaluates the biological integrity, support of aquatic life uses, and probable causes of impairment to those uses, in Bear Creek near Gardiner, Montana. The purpose of this report is to provide information that will help the State of Montana determine whether Bear Creek is water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of use support in this report is based on the species composition and structure of the periphyton (benthic algae, phytobenthos) community at a single stream site that was sampled on July 13, 2000. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992).

Plafkin et al. (1989) and Stevenson and Bahls (1999) list several advantages of using periphyton in biological assessments of streams:

- Algae are universally present in large numbers in all streams and unimpaired periphyton assemblages typically support a large number (>30) of species;

- Algae have rapid reproduction rates and short life cycles, making them useful indicators of short-term impacts;

- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, dissolved salts, and toxins;

- Sampling is quick, easy and inexpensive, and causes minimal damage to resident biota and their habitat;

- Standard methods and criteria exist for evaluating the composition, structure, and biomass of algal associations;

- Identification to species is straightforward for the diatoms, for which there is a large body of taxonomic and ecological literature;

- Excessive algae growth in streams is often correctly perceived as a problem by the public.

- Periphyton and other biological communities reflect the *biological integrity*[1] of waterbodies; restoring and maintaining the biological integrity of waterbodies is a goal of the federal Clean Water Act;

- Periphyton and other biological communities integrate the effects of different stressors and provide a measure of their aggregate impact; and

- Periphyton and other biological communities may be the only practical means of evaluating impacts from non-point sources of pollution where specific ambient criteria do not exist (e.g., impacts that degrade habitat or increase nutrients).

Periphyton is a diverse assortment of simple photosynthetic organisms called algae, and other microorganisms that live attached to or in close proximity of the stream bottom. Most algae, such as the diatoms, are microscopic. Diatoms are distinguished by having a cell wall composed of opaline glass--hydrated amorphous silica. Diatoms often carpet a stream bottom with a slippery brown film.

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Some algae, such as the filamentous greens, are conspicuous and their excessive growth may be aesthetically displeasing, deplete dissolved oxygen, interfere with fishing and fish spawning, clog irrigation intakes, create tastes and odors in drinking water, and cause other problems.

PROJECT AREA AND SAMPLING SITES

The project area is located in southern Park County in southcentral Montana. Bear Creek heads in the Absaroka-Beartooth Wilderness, flows south past the mining town of Jardine, and enters the Yellowstone River about two miles east of Gardiner, Montana just north of Yellowstone National Park (Map 1).

The Bear Creek watershed is within the Middle Rockies Ecoregion of North America (Woods et al. 1999). The surface geology consists of Lower Tertiary volcanic rocks with granitic intrusives, and undifferentiated Precambrian metamorphic rocks (Renfro and Feray 1972). Vegetation is alpine tundra in the headwaters, mixed conifer forest at middle elevations, and mixed grassland at lower elevations (USDA 1976).

A single periphyton sample was collected at a site near the mouth of Bear Creek on July 13, 2000 (Map 1). This site is situated at an elevation of 5,300 feet at Latitude 45 01 55 North, Longitude 110 39 56 West. Bear Creek is classified B-1 in the Montana Surface Water Quality Standards.

METHODS

The periphyton sample was collected by Patrick Newby of the MDEQ Monitoring and Data Management Bureau following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division.

Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the rank of those substrates at the study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's solution.

The sample was examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Dillard (1999), Prescott (1978), Smith (1950), and Whitford and Schumacher (1984). These books also served as references on the ecology of the soft algae, along with Palmer (1977).

After the identification of soft algae, the raw periphyton sample was cleaned of organic matter using sulfuric acid, and two permanent diatom slides were prepared using Naphrax, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). Four hundred and eleven diatom cells (822 valves) were counted at random and identified to species. The following were used as the main taxonomic and autecological references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975. Lowe (1974) was also used as an ecological reference for the diatoms.

The diatom proportional count was used to generate an array of diatom association metrics (Table 1). A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999).

Metric values from Bear Creek were compared to numeric biocriteria developed for streams in the Rocky Mountain Ecoregions of Montana (Table 2). These criteria are based on

metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993). Only periphyton samples collected in summer (June 21-September 21) can be compared with confidence to reference stream samples because metric values change seasonally and summer is the season in which reference streams and impaired streams were sampled for the purpose of biocriteria development.

The criteria in Table 2 distinguish among four levels of impairment and three levels of aquatic life use support: no impairment or only minor impairment (full support); moderate impairment (partial support); and severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor *biological integrity*, respectively.

Quality Assurance. Several steps were taken to assure that the study results are accurate and reproducible.

Upon receipt of the sample, station and sample information were recorded in a laboratory notebook and the sample was assigned a unique number compatible with the Montana Diatom Database: 0787-05. The first part of this number (0787) designates the sampling site (Bear Creek at mouth); the second part of the number (05) designates the number of periphyton samples that have been collected at this site to date for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with station and sample information provided by MDEQ. A portion of the raw sample was used to make duplicate diatom slides. Following the diatom proportional count, the slide used for the count will be deposited in the University of Montana Herbarium in Missoula. The other slide will be retained by *Hannaea* in Helena.

On completion of the project, station information, sample information, and diatom proportional count data will be entered into the Montana Diatom Database.

RESULTS AND DISCUSSION

Results are presented in Tables 3 and 4, located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species' pollution tolerance classes (PTC) and percent abundances, are attached as Appendix A.

SAMPLE NOTES

Bear Creek at mouth. *Hannaea arcus* was present as an epiphyte on *Hydrurus foetidus* and cells were erect and oriented perpendicular to the surface of the host. A large stalked *Gomphoneis (Gomphoneis minuta)* was also present.

NON-DIATOM ALGAE

The benthic flora of Bear Creek was dominated by diatoms, by another chrysophyte--*Hydrurus foetidus*--and by an attached filamentous green alga, *Ulothrix* (Table 3). However, only small patches of filamentous green algae were present in Bear Creek and the amount in the sample probably overestimates the amount in the creek relative to the other algae that were present (Patrick Newby, MDEQ, personal communication). *Hydrurus* is a common alga of cold mountain streams, and is particularly abundant in the Spring. *Ulothrix* also prefers cold waters with moderate nutrient enrichment.

Cyanobacteria, formerly called blue-green algae, were of secondary importance in Bear Creek. In Rocky Mountain streams, cyanobacteria seem to prefer cold waters and low concentrations of nutrients. In reference streams of the Middle Rockies Ecoregion, green and blue-green algae were co-dominants, whereas blue-green algae dominated the benthic floras of less productive streams in the Northern Rockies Ecoregion (Bahls et al. 1992).

Dominance by diatoms and green algae in Bear Creek may indicate somewhat elevated concentrations of nutrients from natural and/or cultural origins.

DIATOMS

The diatom association of Bear Creek was dominated by *Hannaea arcus*, which contributed just over half of the diatom cells (Table 4). *Hannaea arcus* is the unofficial State Diatom of Montana (Bahls 1974) and the namesake of my consulting business. Patrick and Reimer (1966) report it from cool, flowing waters. In a review of 11 diatom ecology papers, Lowe (1974) found *Hannaea arcus* to prefer cold, flowing, and somewhat alkaline waters, and to be indifferent to light organic pollution. In Montana, this species is most abundant in mountain streams on the east side of the Continental Divide (unpublished data).

A recent query to the Internet Diatom List regarding the ecology of this species yielded 15 replies. To summarize the replies, *Hannaea arcus* seems to prefer circumneutral fresh waters, and mountain streams and large cold lakes in northern latitudes, including Himalayan streams and Lakes Superior and Baikal. It has also been reported from high southern latitudes (Antarctica and South Georgia Island). One researcher reported the taxon to be sensitive to pollution from sewage.

The abundance of *Hannaea arcus* in Bear Creek probably reflects the abundance of a preferred host alga (*Hydrurus*) and suitable water quality. Some nutrient enrichment may also be implied by the dominance of *Hannaea arcus* at this site.

Although it contributed only about 5% of the cells, *Gomphoneis minuta* likely contributed a much larger share of the biovolume at this site because of its relatively large size. *Gomphoneis minuta* is found predominantly in the lower reaches of

rivers and inland lakes, from British Columbia south to Arizona, and east to the Atlantic coast in North America, and in Chile in South America; it appears to grow in situations receiving organic inputs (Kociolek and Stoermer 1988).

The other two major diatom species in Bear Creek--*Fragilaria vaucheriae* and *Synedra ulna*--are somewhat tolerant of organic pollution and nutrient enrichment (Lange-Bertalot 1979). Altogether, the major diatom species of Bear Creek indicate cool, flowing, and circumneutral waters with moderate concentrations of dissolved salts and algal nutrients (nitrogen and phosphorus).

With one exception, the diatom metrics of Bear Creek indicated good to excellent water quality and full support of aquatic life uses (Table 4). Because of the large percent abundance of *Hannaea arcus* (50.85%), the percent dominant species metric slightly exceeded the threshold for moderate impairment. Since *Hannaea arcus* may occasionally be found in large numbers in relatively pristine waters (unpublished data), its dominance in Bear Creek may not be due entirely to cultural enrichment.

The Shannon species diversity index was also a bit low in Bear Creek (Table 4), owing in large part to dominance by *Hannaea arcus*. The low diversity index indicated minor impairment but still full support of aquatic life uses.

Two teratological cells of *Hannaea arcus* were observed during the diatom proportional count, indicating minor impairment of aquatic life uses (Table 4). Although diatoms in this family (Fragilariaceae) are prone to deformities, these two abnormal cells may nevertheless indicate chronic toxicity from heavy metals in Bear Creek.

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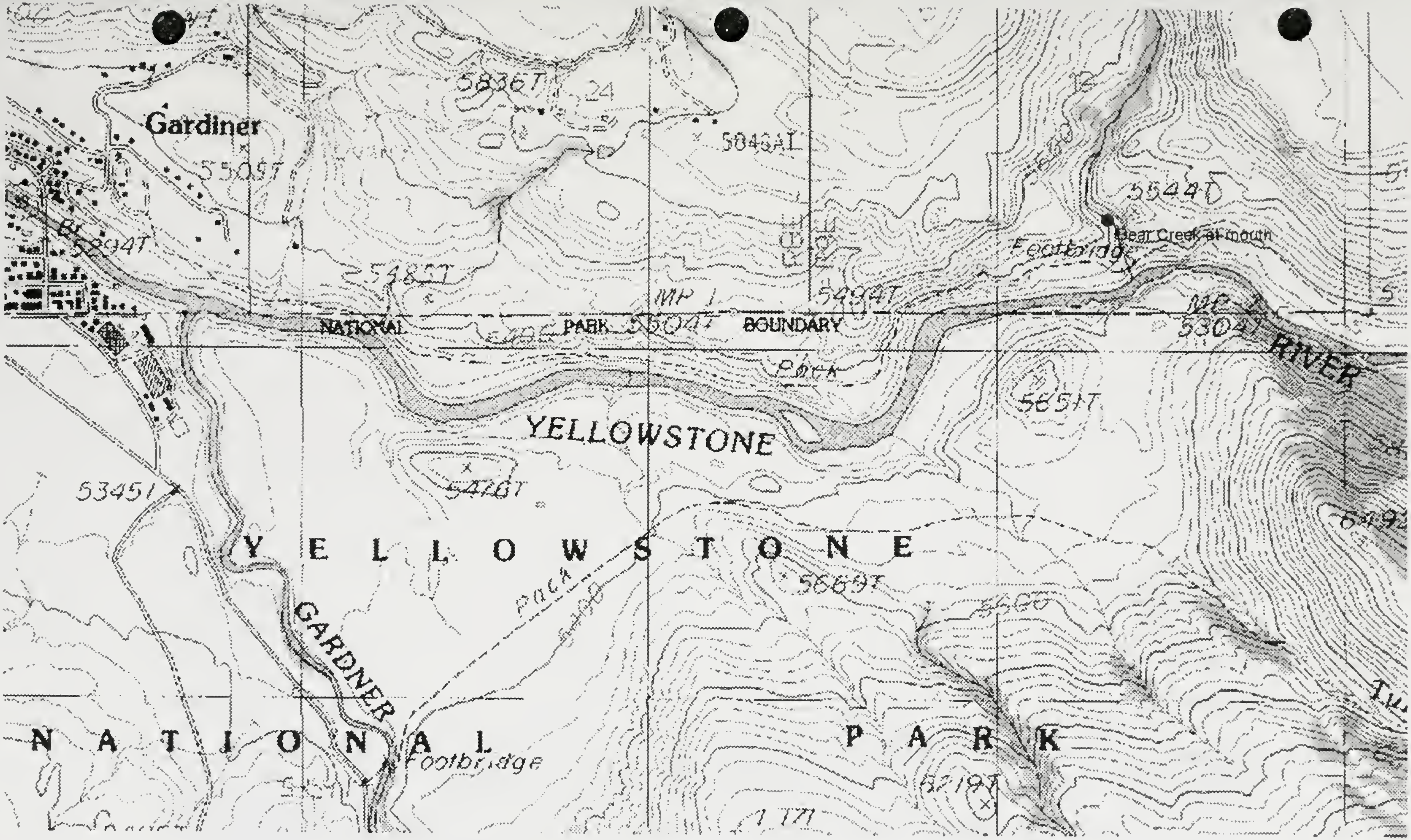

Map 1. Periphyton sampling station on Bear Creek.

'Gardiner, MT'; Scale 1" = 0 238Mi 383Mt 1,258Ft, 1 Mi = 4 197" , 10 cm = 151Mt

Table 1. Diatom association metrics used to evaluate biological integrity in Montana streams: reference, range of values in Montana streams, and expected direction of metric response to increasing anthropogenic perturbation or natural stress.

Metric	Reference	Range of Values	Expected Response
Shannon Species Diversity	Bahls 1979	0.00-5.00+	Decrease[1]
Pollution Index[2]	Bahls 1993	1.00-3.00	Decrease
Siltation Index[3]	Bahls 1993	0.00-90.0+	Increase
Disturbance Index[4]	Barbour *et al*. 1999	0.00-100.0	Increase
No. Species Counted	Bahls 1979, 1993	0-100+	Decrease[1]
Percent Dominant Species	Barbour *et al*. 1999	5.0-100.0	Increase
Percent Abnormal Cells	McFarland *et al*. 1997	0.0-20.0+	Increase
Similarity Index	Whittaker 1952	0.0-80.0+	Decrease
Percent Epithemiaceae	Stevenson & Pan 1999	0.0-80.0+	Decrease
Percent Aerophiles	Johansen 1999	0.0-100	Increase

[1] Shannon diversity and species richness may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increases in nutrients or sediment.

[2] Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

[3] Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*, plus the species *Cymbella sinuata*.

[4] Percent abundance of *Achnanthes minutissima*.

Table 2. Criteria for rating levels of biological integrity, environmental impairment or natural stress, and aquatic life use support in wadeable **mountain** streams of Montana using selected metrics for benthic diatom associations. The lowest rating for any one metric is the overall rating for the study site.

Biological Integrity/ Impairment or Natural Stress/Use Support	Diversity Index (Shannon)	Pollution Index	Siltation Index	Disturbance Index	Number of Species Counted	Percent Dominant Species	Percent Abnormal Cells	Similarity Index[1]
Excellent None/Full Support	>2.99	>2.50	<20.0	<25.0	>29	<25.0	0.0	>59.9
Good/Minor Full Support	2.00-2.99	2.01-2.50	20.0-39.9	25.0-49.9	20-29	25.0-49.9	>0.0-<1.0	40.0-59.9
Fair/Moderate Partial Support	1.00-1.99	1.50-2.00	40.0-59.9	50.0-74.9	10-19	50.0-74.9	1.0-9.9	20.0-39.9
Poor/Severe Nonsupport	<1.00	<1.50	>59.9	>74.9	<10	>74.9	>9.9	<20.0

[1] The Similarity Index or Percent Community Similarity (Whittaker 1952) may be used to compare a study site to an unimpaired upstream control site on the same stream. This metric measures the degree of floristic similarity between diatom associations at the two sites and is the sum of the smaller of the two percent abundance values for each species that is common to both sites. Adjacent riffles on the same stream, without intervening tributaries or environmental perturbations, will generally have at least 60% of their diatom floras in common (Bahls 1993). PCS may also be used to guage the relative amount of impairment or recovery that occurs between adjacent study sites: >59.9% = very similar floras, no change; 40.0-59.9% = somewhat similar floras, minor change; 20.0-39.9% = somewhat dissimilar floras, moderate change; <20.0% = very dissimilar floras, major change.

Table 3. Relative abundance of cells and rank by biovolume of diatoms and genera of non-diatom algae in a periphyton sample collected from the mouth of Bear Creek near Gardiner, Montana on July 13, 2000.

Taxa	Relative Abundance	Rank
Chlorophyta (green algae)		
Ulothrix	abundant[1]	3
Chrysophyta (golden algae)		
Bacillariophyceae (diatoms)	dominant	1
Hydrurus foetidus	abundant	2
Cyanophyta (cyanobacteria)[2]		
Calothrix	occasional	6
Oscillatoria	common	5
Phormidium	frequent	4

[1] Only small patches of filamentous green algae were present in Bear Creek. The amount of filamentous green algae in the sample probably overestimates the amount in Bear Creek relative to other algae (Patrick Newby, MDEQ, personal communication).

[2] Formerly known as blue-green algae.

Table 4. Percent abundance of major diatom species[1] and values of selected diatom association metrics for a periphyton sample collected from the mouth of Bear Creek near Gardiner, Montana on July 13, 2000.

Species/Metric (Pollution Tolerance Class)[3]	Percent Abundance/Metric Value[2]
Fragilaria vaucheriae (2)	15.69
Gomphoneis minuta (3)	5.11
Hannaea arcus (3)	50.85
Synedra ulna (2)	5.47
Cells Counted	411
Total Species	32
Species Counted	30
Species Diversity	<u>2.82</u>
Percent Dominant Species	**50.85**
Disturbance Index	0.73
Pollution Index	2.74
Siltation Index	2.18
Percent Abnormal Cells	<u>0.24</u>
Percent Epithemiaceae	0.24

[1] A major diatom species is here considered to be one that accounts for 5% or more of the cells in one or more samples of a sample set.

[2] <u>Underlined values</u> indicate good biological integrity, minor impairment, and full support of aquatic life uses; **bold values** indicate fair biological integrity, moderate impairment, and partial support of aquatic life uses; all other values indicate excellent biological integrity, no impairment, and full support of aquatic life uses.

[3] 3 = sensitive to pollution; 2 = tolerant of pollution; 1 = most tolerant of pollution (no class 1 diatoms were major species in this sample).

APPENDIX A: DIATOM PROPORTIONAL COUNT

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
078705	Achnanthes lanceolata	2	9	1.09
078705	Achnanthidium minutissimum	3	6	0.73
078705	Cocconeis placentula	3	5	0.61
078705	Cymbella cymbiformis	3	1	0.12
078705	Diatoma mesodon	3	19	2.31
078705	Epithemia turgida	3	2	0.24
078705	Fragilaria brevistriata	3	14	1.70
078705	Fragilaria construens	3	4	0.49
078705	Fragilaria leptostauron	3	5	0.61
078705	Fragilaria pinnata	3	2	0.24
078705	Fragilaria vaucheriae	2	129	15.69
078705	Gomphoneis eriense	3	24	2.92
078705	Gomphoneis minuta	3	42	5.11
078705	Gomphonema angustatum	2	5	0.61
078705	Gomphonema mexicanum	2	2	0.24
078705	Gomphonema minutum	3	8	0.97
078705	Gomphonema olivaceoides	3	13	1.58
078705	Gomphonema olivaceum	3	9	1.09
078705	Gomphonema pumilum	3	8	0.97
078705	Hannaea arcus	3	418	50.85
078705	Meridion circulare	3	4	0.49
078705	Navicula absoluta	2	0	0.00
078705	Navicula minima	1	2	0.24
078705	Nitzschia dissipata	3	8	0.97
078705	Nitzschia palea	1	0	0.00
078705	Nitzschia paleacea	2	3	0.36
078705	Nitzschia perminuta	3	4	0.49
078705	Reimeria sinuata	3	1	0.12
078705	Rhoicosphenia curvata	3	16	1.95
078705	Stephanodiscus hantzschii	2	1	0.12
078705	Stephanodiscus medius	2	13	1.58
078705	Synedra ulna	2	45	5.47